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Unveiling the Interplay of Students' Epistemic Emotions and Knowledge Building Activities in Design Studios

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Abstract: Educational research may have established intricate connections between student achievements and emotions, but there remains a need to conduct more research on the crucial role of students' epistemic emotions during learning. The emergence of global knowledge societies has nudged researchers to delve deeper into the understanding of students' epistemic emotions within evolving learning environments, such as knowledge building environments that encourage complex learning and knowledge creation. This study addresses this gap via a naturalistic study of students' epistemic emotions in a student Knowledge Building Design Studio (sKBDS). We aim to illuminate the intersections between epistemic emotions and knowledge building activities, with findings to inform the design of more rigorous studies and designs to advance knowledge building practices. An Epistemic Emotion Survey (EES) was adapted for gathering students' epistemic emotions and to align with knowledge building activities in the sKBDS. A total of 1,022 sets of epistemic emotion data from 73 primary and secondary school students were collected from two runs of the sKBDS, compiled into a single repository for descriptive analysis. Findings show that students experienced heightened curiosity, interest, excitement, and were generally happy to participate in activities at the sKBDS, while demonstrating relatively less anxiety, frustration, and confusion when undergoing knowledge building activities. Throughout the sKBDS, students also exhibited surprise at planned activities and what they have discovered and worked on. In addition, knowledge building activities also had varying effects on students' emotions, ranging from tiredness and hunger to occasional positive feelings. Overall, the findings from this study will be used for improving knowledge building practices and designs in future design studios, with implications for educators, students, and researchers.

Keywords: Epistemic emotions, knowledge building, design studio, descriptive analysis

1. Introduction

Educational research studies have recognized that performance effects such as success and failure are often linked to emotions such as anxiety and pride (e.g., Lazarus, 2000; Pekrun, 2018; Tulis & Ainley, 2011). Students who exhibit positive emotions (e.g., enjoyment and pride) positively predicted subsequent achievement while negative emotions (e.g., anxiety and boredom) negatively predicted achievement, indicating the importance of understanding students' emotions for achievement and of achievement for the development of emotions (Pekrun et al., 2017). However, researchers have also begun to acknowledge that emotions triggered by the cognitive characteristics of tasks can also be crucially important for learning, and such emotions include surprise, boredom, curiosity, or confusion about contradictory information (ibid). These affective states represent epistemic emotions due to how they relate to the knowledge-generating qualities of cognitive activities (Morton, 2010).

Epistemic emotions as cognitive dimensions are essential for complex learning and knowledge creation, both of which are related to idea-generation and knowledge creation qualities, and even emotions such as confusion can be beneficial for learning (D'Mello et al.,

2014). Recent research has also shed light on the significance of seemingly negative emotions like frustration and confusion, which can positively influence cognitive processing and learning outcomes (Pekrun & Stephens, 2012).

Within the dynamic landscape of modern education, the need to delve deeper into students' epistemic emotions within evolving learning environments is accompanied by a burgeoning awareness of the cognitive facets inherent in students' exploration and inquiry processes that are key to complex learning (Pekrun & Stephens, 2012). As more knowledge-based activities are designed and implemented in a world where students become emergent knowledge workers in global knowledge societies, this study showcases a naturalistic study of students' emotions in a complex learning environment, and to illuminate the intersections between students' epistemic emotions and learning that help advance the designs of more systematic and rigorous studies to impact knowledge building practice.

The following research question is addressed in this study: What are the relationships between students' epistemic emotions and the knowledge building activities within a student Knowledge Building Design Studio?

2. Background and Literature Review

2.1 Epistemic Emotions and Student Learning

Whether epistemic emotions facilitate or constrain learning, the interplay between epistemic emotions and learning outcomes is considered complex (Baker et al., 2010). Epistemic emotions such as curiosity generally enhance interest and engagement, leading students to adopt flexible and creative learning strategies (Pekrun, 2017). Conversely, when students worry, their frustration and boredom may also lead to positive learning outcomes (Muis et al., 2015). For this study, the choice of epistemic emotions stems from an existent scale (Pekrun et al., 2017) and will be used to align with knowledge building activities in the student Knowledge Building Design Studio to uncover underlying relationships and associations.

2.2 The student Knowledge Building Design Studio (sKBDS)

To better explore and comprehend students' epistemic emotions, an innovative and authentic learning environment like the student Knowledge Building Design Studio (sKBDS; Yuan et al., 2023) has been designed and developed for students, teachers, researchers, and experts to explore real-world problems that are relatable to current participants (e.g., sustainability issues and global climate change). The sKBDS is also a platform that provides the opportunity to bring various communities (i.e., educators, students, experts, researchers from across the world) together to interact with cross-community ideas that can lead to knowledge building and pedagogical transformations. Grounded in knowledge building principles (Scardamalia, 2002), the sKBDS provides a platform for students to engage in collaborative knowledge construction and critical thinking, while also acknowledging and examining their expressed emotions as integral components of the learning process. As education evolves and integrates emerging technologies such as Artificial Intelligence, the understanding of students' ideas (Lee, 2023) and epistemic emotions (Teo et al., 2022) becomes increasingly vital in the continuous endeavor to reveal insights into the innate thinking and consequent actions of students as they become competent knowledge builders in knowledge societies.

Within this study's context, the sKBDS can be broken down into several phases, namely engagement of students for ideation at the start, followed by idea improvement processes within smaller groups before merging into larger groups, and ending with a gallery walk for students to share their investigations and work. Underlying these processes are reflections that students will continuously work on and the emotion surveys that help provide data for this study.

2.3 Need for Further Exploration of Epistemic Emotions during Knowledge Building

The use of knowledge building in various disciplines has been quite prevalent in recent years (Chen & Hong, 2016) and the sharing of diverse ideas and theories between students and external communities from different fields have also led to increasing acknowledgement and recognition of the importance of epistemic emotions (Teo et al., 2022). However, this field is under-researched, especially in the exploration of relationships and associations between students' epistemic emotions and the knowledge building activities they are engaging in.

One of the key reasons is that the study of student emotions is non-trivial and complex, let alone in a knowledge building environment where there is unpredictability due to wide-ranging student learning trajectories involving diverse ideas, which therefore requires the study to be addressed in a multimodal fashion with mixed methods (e.g., Lee & Tan, 2017; Teo et al., 2022). In previous studies of student epistemic emotions within sKBDS, a broad range of students' epistemic emotions during collaborative discourse were explored and findings show that emotional behavior appears more heightened when students engaged in sense-making and negotiation of their ideas (Teo et al., 2022). Multimodal data in an authentic knowledge building environment were collected and analyzed, including student facial and heart rate variability data (Lee et al., 2023), with the use of machine learning to discern and validate epistemic emotions. Another emergent method such as Epistemic Network Analysis (ENA) was also implemented to reveal clear differences between group and individual engagements, online and in-person verbal discourse, revealing that students were more cognitively engaged in online discussions than in-person group verbal talk (Ong et al., 2023).

Within this study, the aim is to further the understanding of students' epistemic emotions in relation to the activities that are held within the sKBDS, and to bridge this research gap in knowing how epistemic emotions can facilitate or constrain students' learning processes and outcomes (Baker et al., 2010).

3. Method

3.1 Settings, Participants, and Procedure

Data for this study was obtained from two runs of the student Knowledge Building Design Studio (sKBDS), which were held in June and October 2023. Each sKBDS run was a two-day event where educators, students, international experts, and researchers converged in-person and virtually to engage in exploration and inquiry while displaying cognitive characteristics that are key to complex learning. The planned activities seek to stimulate student's ideation capabilities, allowing students the space to interact and build on each other's ideas, and to collectively rise above and advance knowledge together as a community.

A total of 73 students (ages 10 to 15 years old, Primary 5 to Secondary 3, or Grade 5 to Grade 10) from primary and secondary schools were involved in both runs. The gender breakdown was not tracked as we were not comparing students, and the sample size was based on the availability of participants. A total of 1,022 sets of epistemic emotion data were collected from the two iterations of sKBDS and compiled into a single repository for this study's analysis as the activities in both runs were largely similar in terms of structure and procedures.

To acquire students' epistemic emotion data, Epistemic Emotion Surveys (EES) in the format of virtual forms were issued to students at critical junctures between knowledge building activities to capture students' expressed emotions during the activities, which are considered important drivers of knowledge exchanges between students and the external communities. These junctures are also often before and after critical knowledge building activities to capture the changes and trends of students' epistemic emotions as they navigate the day's activities.

Figure 1 shows the activities that were held for the October 2023 run, with a similar plan of knowledge building activities in the June 2023 run. Survey results from both runs were examined and cross-validated along similar activities to discern patterns of students' epistemic emotions against knowledge building activities.

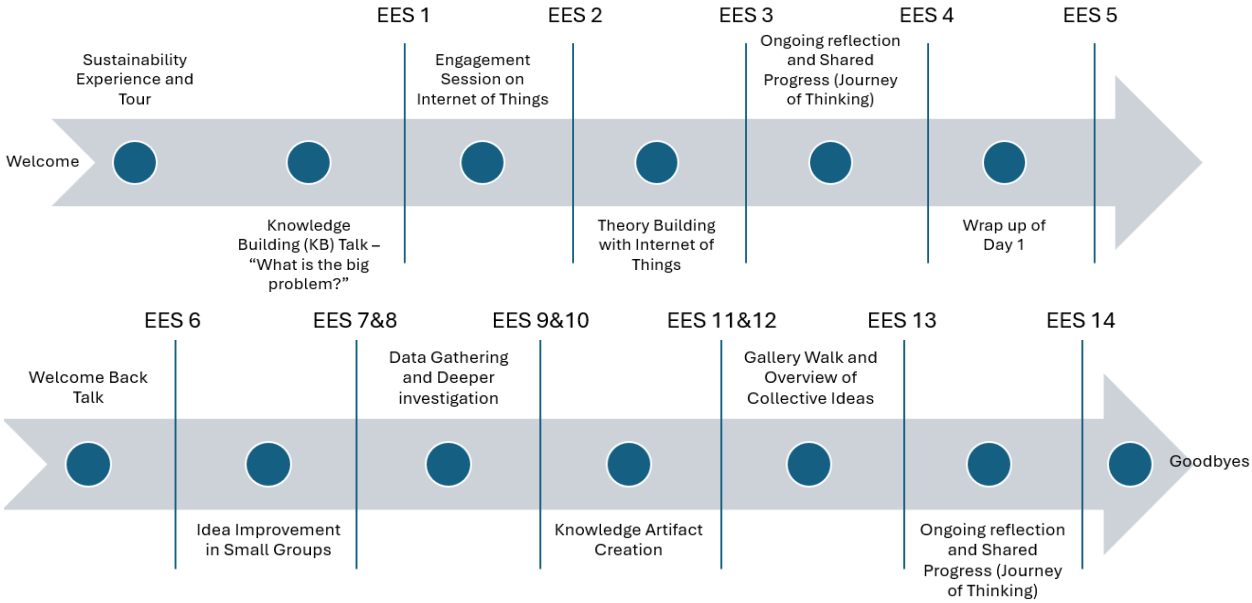


Figure 1. Timeline of critical junctures where EES was conducted during the second sKBDS (October 2023), with similar plans in the first run (June 2023).

3.2 Epistemic Emotion Survey (EES) in this Study

The survey implemented in this study is called the Epistemic Emotion Survey or EES in short, adapted from Pekrun et al's self-report instrument (2017) named Epistemically-Related Emotion Scales, which captures the major emotions that occur frequently in epistemic contexts and are functionally relevant for learning and cognitive problem solving. The emotions that are adapted and covered in this study's EES include the emotions from the seven-item short version of the scales, also seen in other prominent studies (e.g., Muis et al., 2015), namely, anxious, bored, confused, curious, excited, frustrated, and surprised. Three more emotions from the full scale were also included, such as interested, happy, and sad. These epistemic emotions are selected based on cognitive appraisals about the (mis-)alignment between new information and existing knowledge or beliefs and were also used to tease out possible indicators that reflect a student's affective state at the time of survey. An open-ended question at the end of the survey helps to acquire potential responses that students may want to surface or share with the research team, which are also not present on the survey instrument.

Altogether, ten emotions are presented to students on a 5-point Likert scale varying from "not at all" to "moderate" and to "very strong", as shown on the EES scale in Table 1. Since the EES was adapted from Pekrun et al's (2017) established scale with proven validity and reliability, the use of confirmatory factor analysis is less critical, considering that this research is not for comparative purposes and also focused on using descriptives to explore the relationships between students' epistemic emotions and the knowledge building activities.

Table 1. Epistemic Emotion Survey (EES) adapted from Pekrun et al's (2017) scale

	Not at all	Very little	Moderate	Strong	Very Strong
Anxious	1	2	3	4	5
Bored	1	2	3	4	5
Confused	1	2	3	4	5
Curious	1	2	3	4	5
Excited	1	2	3	4	5
Frustrated	1	2	3	4	5

Happy	1	2	3	4	5
Interested	1	2	3	4	5
Sad	1	2	3	4	5
Surprised	1	2	3	4	5
Others	Open-ended field for student's inputs (if any)				

Note: This study's EES covers the seven-item short version and three items from the full version, along with an open-ended field for student inputs, if any.

3.3 Descriptive Analysis

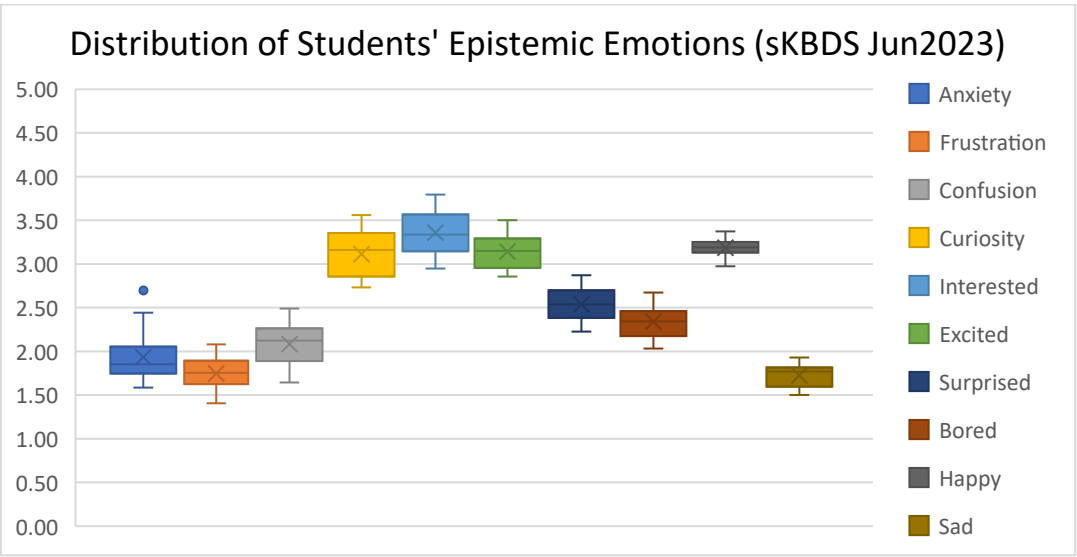
The collected data will be analyzed to describe how students' epistemic emotions vary with the knowledge building activities. The form of descriptive analysis will be in the form of frequency distribution analysis with methods of dispersion, and the use of summary statistics and data visualization for providing insights that can be interpreted and for discovering potential relationships. Students' epistemic emotion scores of 1 to 5 will be averaged across the group of participants within a specific survey, and since no baseline emotion scores are available, the 10 emotion scores will be relatively interpreted and mapped against the ongoing knowledge building activities. Apart from aggregated emotion scores, a list of frequent words that students chose to share via the survey will also be qualitatively interpreted from a customized word cloud (no stop words with top 15-word limit).

4. Findings and Discussion

4.1 Distribution and Aggregation of EES Scores

The findings first show the distribution of EES scores representing students' epistemic emotions across the two runs of sKBDS, which were aggregated and shown in the form of box-and-whisker plots (Figure 2). The majority of scores can be determined in a glance with any potential outliers.

From the data patterns in Figure 2, students experienced heightened curiosity, interest, excitement, and were generally happy to participate in activities at the sKBDS. They also demonstrated relatively less anxiety, frustration, and confusion when undergoing knowledge building activities. Throughout the sKBDS, students were also significantly surprised at the planned activities and at what they discovered and worked on. Overall, emotion scores were not widely varying (tight range) with few outliers (dots) in the entire dataset.



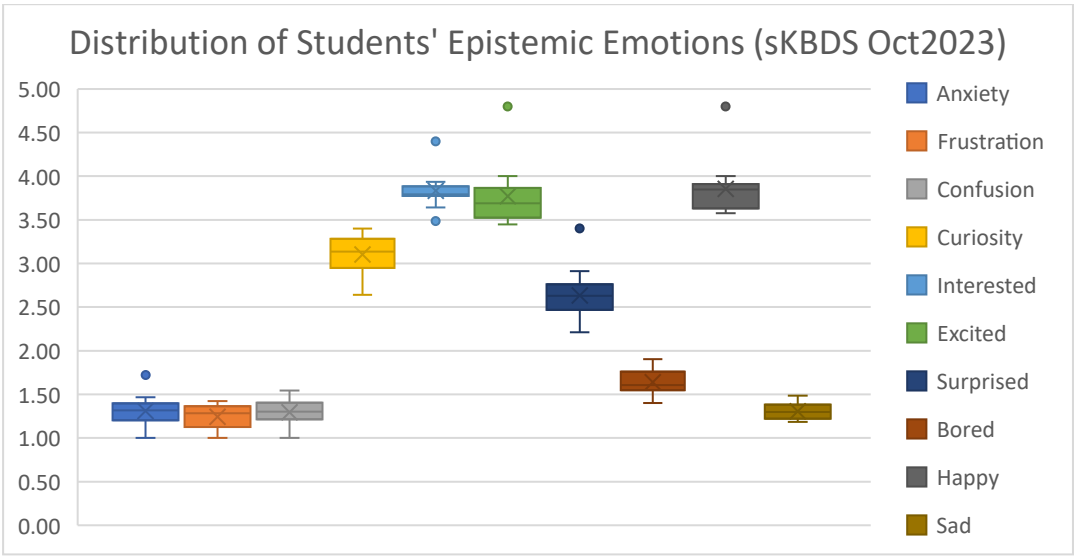


Figure 2. Distribution of students' EES scores across the two runs of sKBDS in June and October 2023 (top and bottom respectively).

The EES data were then analyzed in a temporal manner, plotting students' epistemic emotions against the knowledge building activities that were bounded by the 14 EES in each run of the sKBDS. Findings are presented in Figure 3, showing the individual epistemic emotions that were reported at each EES juncture and notable observations are being highlighted in the following list below.

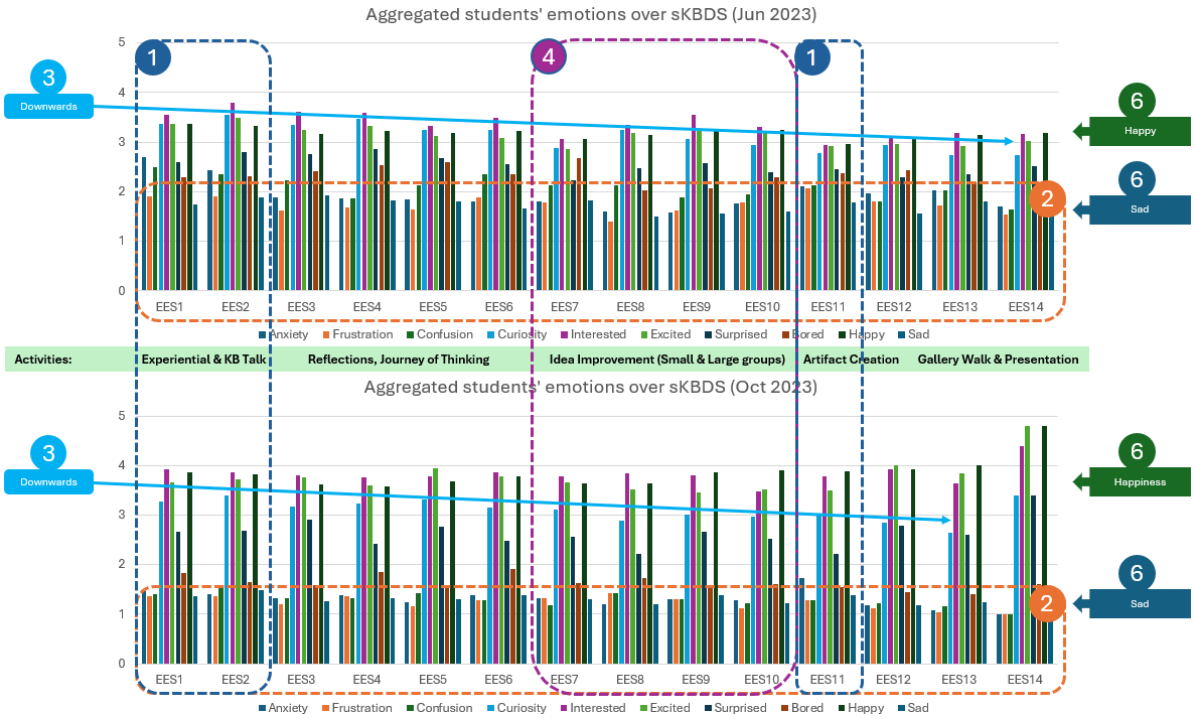


Figure 2. Aggregated students' EES scores across the two runs of sKBDS in June and October 2023 (top and bottom respectively). Notable observations are numbered and discussed in the paper.

Based on the 5-point Likert scale in Table 1 and the aggregated scores in Figure 2, several relationships between students' epistemic emotions and the knowledge building activities bounded by EES junctures are as such (observations are numbered and referred in Figure 2):

1. *Anxiety* – Students were found to be slightly anxious with average scores of 2.00±0.33 (standard error of the mean, SEM) within the first two EES (EES1 and 2) before settling down. Students were anxious again (1.91±0.19) at the EES11 juncture when they were preparing to conduct in-person presentations to the entire community.
2. *Frustration and Confusion* – There is little to no frustration (1.49±0.04) and confusion (1.69±0.05) as students either scored 1 or 2 (indicating none or little frustration and confusion) throughout the sKBDS.
3. *Curiosity* – Students' curiosity generally starts on a high (peak of 3.32) and wanes throughout the sKBDS towards the end (3.10), except for an outlier at the end of the run in October 2023.
4. Interest and Excited – Students' interest and excitement peaks (3.86 and 3.61 respectively) within the first two EES (EES1 and 2) and wanes after students settled down for activities, before peaking again between EES7 to EES10, contributing to a cyclical behavior.
5. Surprised and Bored – Students were consistently and slightly surprised (2.59±0.07), and a little bored (1.99±0.05) throughout the two runs of sKBDS.
6. Happiness and Sadness – Students felt happier (3.52±0.05) than sad (1.51±0.03) at all times during the sKBDS, except for an outlier at the end of the run in October 2023.

4.2 Other Emotions Surfaced by Students

There were several interesting insights from other responses that the students chose to share via the survey. These student inputs are optional and voluntarily contributed, mostly including emotions that students were feeling otherwise or descriptives that they felt were not covered by the survey and hence they wanted to indicate them in the survey. Figure 3 shows the resultant word cloud of the top 15 words or terms that were based on this list of other responses that students wanted to include.

Figure 3. Word cloud of top 15 words that students indicated alongside the list of emotions already in the EES.

Several insights from the interpretation of this list of emotions stand out. Firstly, throughout the two runs, students predominantly felt tired and hungry, which occurred 94 and 67 times respectively, representing 15% of all student responses. These are two states that indicated the level of energy or fatigue and are sometimes conceptualized as emotions (MacCormack & Lindquist, 2019). Another state of students being sleepy is also rather common (42 times), followed by nil, nothing, or "idk" ("I don't know"), which formed an interesting insight, as students felt indecisive of how they feel, or they did not feel strongly about any particular emotion. An additional insight was that several students felt the need to indicate that they felt good, a positive emotion (Fredrickson, 2003) despite the majority of neutral to negative emotions listed after activities. In this study, hunger, tiredness, and

sleepiness are considered bodily states and should not be mistaken as negative emotions themselves, although they can definitely influence emotions.

What can we make of this? Overall, these findings suggest that the knowledge building activities may have varying effects on students' emotions, ranging from tiredness and hunger to occasional positive feelings. It however does highlight the importance of considering not only typical emotions but also other states such as tiredness and hunger when assessing students' emotional responses to knowledge building activities, which tend to be epistemic.

4.3 Answering the Research Question

The above findings provide a descriptive (quantitative and qualitative) interpretation and perspective of the relationships between students' epistemic emotions and the knowledge building activities within a student Knowledge Building Design Studio. Considering the smaller sample size of 1,022 datasets from 73 students, the intention of this paper is not to generalize possible findings to be applicable to larger settings, but rather to assist us in gaining a better understanding and for redesigning the sKBDS to be more student centric and with consideration of students' epistemic emotions. With findings and insights from this study, we answer the research question of uncovering "what are the relationships between students' epistemic emotions and the knowledge building activities within a student Knowledge Building Design Studio".

Firstly, it was apparent that students experienced slight to moderate anxiety when approaching or starting in new contexts, such as the beginning of the sKBDS, or when asked to present to a larger crowd. This happened even though students were prepped at the start with clear expectations of what the sKBDS will entail, and hence might be inevitable and difficult to avoid. However, future sessions can anticipate this development and plan for it so as to seamlessly assuage students' anxiety and to ease them into the proceedings.

Secondly, students demonstrated higher level of interest and excitement during the ideation and engagement phases of the sKBDS, which are experiential and part of knowledge building talks that were often unique opportunities that students do not normally encounter in mainstream lessons. This also provided students with the momentum to be continuously involved in subsequent idea improvement processes and further investigations during small and larger group discussions. In the long run, one way of sustaining students' interest and excitement is to conduct continuous engagement, which is admittedly a very arduous and tedious process for any educator and engager. On the bright side, the positive start in getting students interested and excited does smoothen students' transition into the slightly "drier" parts of the sKBDS, which include requesting students to conduct reflections (as part of the "Journey of Thinking") and creating artifacts for gallery walk or presentations.

Thirdly, students' curiosity is not inhibited throughout the sKBDS but slightly and naturally waned over the two days as novelty wears off. However, it is noted that the decrease is minimal (less than a fifth of a point), and curiosity is considered to be largely sustained throughout sKBDS. This could be attributed to the nature of the sKBDS that leverages the idea-centric principles of knowledge building and allows students to exhibit agency and work on authentic topics that are relevant to them, thereby sustaining their curiosity and interest to continue investigations and development work. The findings are also in line with recent research indicating curiosity and joy (i.e., happiness) help students in knowledge creation and knowledge building (Yang et al., 2024). The use of authentic and relevant talking points is a potential consideration to contemplate during planning of design studios.

Lastly, some focus should also be given to the learning environment that contributes to students' learning and affects their epistemic emotions. Within a knowledge building environment such as the sKBDS, students were able to ideate and reflect on topics that are of interest and relevance to them, after which they improved their ideas and constructed artifacts that represented their cumulative achievements over the two days of sKBDS. By allowing students to work on topics that are not bounded by curriculum and without fear of reprisal, students experienced little to no frustration and confusion throughout the sKBDS, contributing to a conducive and productive learning environment for all students.

5. Limitations

The self-reporting nature of student emotions may be one of the more accurate ways of knowing students' epistemic emotions at any given point in time during planned activities, due to minimal interpretation efforts that result in inaccurate findings. However, it is also essential to approach the scores obtained from the EES with caution, considering the precise instructions and epistemic context outlined for responding to the instrument. There are also other environmental and contextual factors, such as when students commonly experienced survey fatigue towards the end of the sKBDS sessions, which may contribute towards rushed completion and partially inaccurate answers that can potentially affect survey results.

It is also worth noting that since this study stemmed from a multimodal learning analytics project, there are efforts to further validate and generalize the findings using multiple data sources and analyses from student interviews and facial analysis. However, these were not reported due to the focus on the self-reporting EES instrument that is considered more reliable than other data sources and analyses. Additionally, while the EES instrument assessed the major epistemic emotions, it may not encompass all varieties of such emotions due to specific research needs and the context of implementation. The current instrument has an open-ended question to ask if students are experiencing other emotions and although the response to this question was very limited in our existing data, we can reference it as part of attempts to develop supplementary scales for emotions that were less experienced in sKBDS.

6. Conclusion

This study was borne out of a desire to investigate the relationships between students' epistemic emotions and knowledge building activities within design studios, with understandings to improve educational outcomes and advance the designs of more systematic and rigorous studies that impact knowledge building practice. The adapted use of EES within the sKBDS has proved to be a reliable approach and method to examine a larger range of emotions beyond basic emotions that often occur during learning. It was also critical to be able to study and learn more about how epistemic emotions occur during epistemic activities, such as students' knowledge building. While there may be alternative methods such as physiological methods to measure students' vital signs or conducting of student behavioral observations, the EES instrument is considered a less intrusive and potentially more effective and accurate method to keep track of students' emotions and minimalize impact on students' activities within an authentic learning environment. Moving forward, it will be critically important to leverage and integrate the use of Artificial Intelligence-powered solutions such as facial recognition with the EES instrument to complement each other and for cross-validation. These can potentially be part of concerted efforts for deeper study of students' learning processes such as ideation, knowledge creation, improvement, and problem solving.

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